NCEP Cloud-Climate Process Team (CPT2)

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Goals for CPT2

Building on previous results of Sc-Cu transition CPT,

- ❑ Improve global cloud and precipitation climatology of GFS+MOM (Modular Ocean Model) through better cloud microphysical and macrophysical schemes (NCEP, UW).
- ❑ Implement a moist Eddy-Diffusion Mass-Flux (EDMF) planetary boundary layer (PBL) scheme within the NCEP global forecasting system (GFS) that improves operational weather and coupled climate forecasting (JPL, NCEP, UW).
- ❑ Compare GFS-forecast clouds with versions of GFDL climate model run in initialized weather forecast mode (NCEP, GFDL, UW) for improving cloud micro/macrophysics schemes.

NOAA Sc-Cu Transition CPT (2010-2013)

Goal: Improve the representation of the cloudy boundary layer in NCEP GFS and NCAR CAM5 with a focus on the subtropical stratocumulus to cumulus (Sc-Cu) transition

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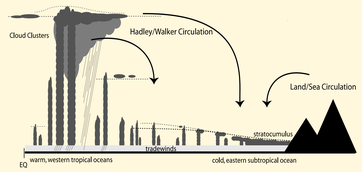
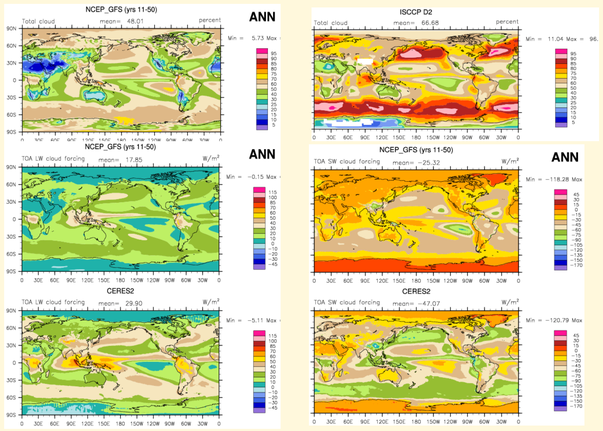


❖ Key GFS diagnostic findings (Xiao et al. 2014 *Clim. Dyn.*)

- ➢ GFS and CFSv2 have too little cloud almost everywhere
- ➢ GFS loses 5-10 W m^{-2} from neglect of TKE dissipation heating
- ➢ GFS subtropical Sc maxima are too far offshore.
- ➢ Otherwise, GFS+MOM makes an excellent climate model



GFS atmospheric energy leak

1 year coupled GFS runs	TOA (W/m^2)	SFC (W/m^2)	Difference (W/m^2)
CTL	9.9	5.3	4.6
EXP	1.5	0.8	0.7

Add TKE dissipation heating (Han & Pan)

$$\varepsilon \approx \underbrace{-K_h \frac{g}{\theta_v}\frac{d\theta_v}{dz}}_{\text{buoyancy production}} + \underbrace{K_m \left|\frac{d\mathbf{u}}{dz}\right|^2}_{\text{sheap production}} \qquad c_p \frac{\partial \overline{T}}{\partial t} \approx \varepsilon$$

- TOA: mean energy budget at the top of the atmosphere (=downward shortwave flux-[upward shortwave flux+upward longwave flux])
- SFC: mean energy budget at the surface (=downward shortwave flux+downward longwave flux-[upward shortwave flux+upward longwave flux+latent heat flux+sensible heat flux])
- With TKE dissipative heating, atmospheric energy loss (Difference) is much smaller.
- Dissipative heating also increases hurricane intensity.

Sc-Cu CPT model improvement work

- ➢ Developed new unified cloud fraction scheme (Sun & Pan) in place of separate schemes for radiation, microphysics. This somewhat increases global cloud cover in parallel forecast tests
- ➢ Showed that LES-suggested changes to shallow cumulus parameterization also increase global cloud cover (Fletcher et al. 2014, *GMDD*).
- ➢ Added TKE dissipation heating scheme (Han & Pan)
- ➢ Implemented a hybrid EDMF PBL scheme into GFS (Han et al.)

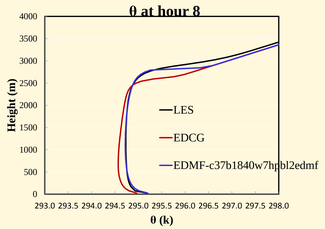
These all underwent parallel forecast testing with mixed results and the TKE dissipative heating scheme and the hybrid EDMF PBL scheme have been adopted in the next operational GFS as they show positive impacts on the GFS forecast skill.

EDMF PBL scheme

$$\overline{w'\phi'} = -K\left(\frac{\partial \overline{\phi}}{\partial z} - \gamma\right) \quad \Rightarrow \quad \overline{w'\phi'} = -K\frac{\partial \overline{\phi}}{\partial z} + M(\phi_u - \overline{\phi})$$

Current operational GFS PBL scheme (EDCG scheme)

EDMF PBL scheme (Siebesma et al., 2007)



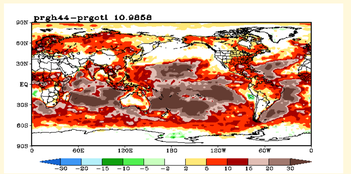
Problems of full EDMF PBL scheme

- Large tropical wind vector RMSE.
- Too much increase of low cloud fraction over Tropics.
- These negative impacts are mainly due to too much vertical mixing by the EDMF scheme over the Tropics where a strongly unstable PBL is hardly found.

Development of hybrid EDMF PBL scheme

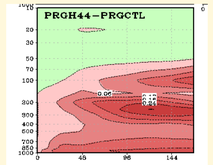
- ➢ A hybrid EDMF scheme is developed, where the EDMF scheme is applied only for the strongly unstable PBL, while the EDCG scheme is used for the weakly unstable PBL.
- ➢ The rationale for the hybrid scheme is that the MF scheme works well for the cases with coherent, well-organized updrafts, such as cumulus convection and strong thermals in CBL, whereas it may not work well for the weakly unstable PBL where the larger eddies easily break into smaller ones and hardly maintain a coherent structure.
- ➢ The Tropics are largely occupied with ocean where a strongly unstable PBL is hardly found. Therefore, the EDCG scheme is mostly called over the Tropics in the hybrid scheme.

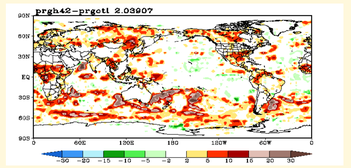
Low cloud fraction



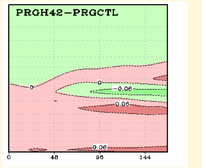
Full EDMF

Tropical wind vector RMSE





Hybrid EDMF



Strategy for the CPT2 model improvement work

- ❑ Find the weaknesses of the system by analyzing its simulation results and identify the relevant processes.
- ❑ Use benchmark LES and single-column model (SCM) to test possible improvements to the parameterizations of the processes.
- ❑ Test the proposed improvements in short global integrations either in free-run mode or with data assimilation